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Technical Report Series on the Boreal Ecosystem-Atmosphere Study (BOREAS)

Forrest G. Hall and Jaime Nickeson, Editors

Volume 78 BOREAS RSS-20 POLDER C-130 Measurements of Surface BRDF

M. Leroy

National Aeronautics and Space Administration

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BOREAS RSS-20 POLDER C-130 Measurements of Surface BRDF

Marc Leroy

Summary

This BOREAS RSS-20 data set contains measurements of surface BRDF made by the POLDER instrument over several surface types (pine, spruce, fen) of the BOREAS SSA during the 1994 IFCs. Single-point BRDF values were acquired either from the NASA ARC C-130 aircraft or from a NASA WFF helicopter. A related data set collected from the helicopter platform is available as is POLDER imagery acquired from the C-130. The data are stored in tabular ASCII files.

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1. Data Set Overview

1.1 Data Set Identification

BOREAS RSS-20 POLDER C-130 Measurements of Surface BRDF

1.2 Data Set Introduction

The POLarization and Directionality of Earth Reflectances (POLDER) instrument measures Bidirectional Reflectance Distribution Function (BRDF) and Bidirectional Polarization Distribution Function (BPDF) of terrestrial surfaces in several visible and near-infrared spectral bands. The instrument scanned several surface types (pine, spruce, fen, and others) in the BOReal Ecosystem-Atmosphere Study (BOREAS) Southern Study Area (SSA) during the Intensive Field Campaigns (IFCs) in 1994. Single-point BRDF measurements were acquired either from the C-130 aircraft or the helicopter. POLDER images acquired from the C-130 are also available for illustration purposes.

1.3 Objective/Purpose

The objective of the investigation was to characterize the bidirectional reflectance properties of different cover types in boreal forests over several seasons. This characterization can then be used to retrieve biophysical parameters such as Leaf Area Index (LAI), chlorophyll content, and structural canopy parameters, either through the use of semi-empirical relations between reflectances and biophysical parameters, or through the inversion of a BRDF radiative transfer model. The overall goal is to establish methodologies for monitoring the ecological state of the boreal forest using remote sensing techniques.

1.4 Summary of Parameters

Surface bidirectional reflectance derived from multiangular C-130 measurements over the tower sites.

1.5 Discussion

The POLDER instrument measures surface reflectance as a function of wavelength and observation geometry. This data set comprises individual site measurements of surface BRDF made by the POLDER instrument over several surface types (pine, spruce, fen) in the BOREAS SSA, acquired during the 1994 IFCs.

1.6 Related Data Sets

BOREAS RSS-01 PARABOLA SSA Surface Reflectance and Transmittance Data BOREAS RSS-02 Level-1b ASAS Imagery: At-sensor Radiance in BSQ Format BOREAS RSS-03 Reflectance Measured from a Helicopter-Mounted Barnes MMR BOREAS RSS-11 Ground Network of Sun Photometer Measurements BOREAS RSS-20 POLDER Helicopter-Mounted Measurements of Surface BRDF

2. Investigator(s)

2.1 Investigator(s) Name and Title

Dr. Marc Leroy Dr. François-Marie Brèon Patrice Bicheron Olivier Hautecoeur

2.2 Title of Investigation

Estimation of Photosynthetic Capacity using POLDER Polarization

2.3 Contact Information

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3. Theory of Measurements

POLDER is an optical sensor designed to observe the surface reflectance in visible and near-infrared bands. The main characteristic of the POLDER instrument is that it can observe an area from multiple directions. POLDER has a wide field-of-view (FOV) lens with \pm 51° along-track and \pm 43° cross-track viewing, and a charge-coupled device (CCD) array detector to collect images.

Two principles of operation should be distinguished during the BOREAS experiment. When POLDER was mounted on the helicopter, the purpose was to collect data over the target at a low altitude, typically 300 m. One image acquired directly over a homogeneous surface provides the BRDF of the experimental site. From the National Aeronautics and Space Administration's (NASA) Ames Research Center (ARC) C-130 aircraft, at high altitude, typically 5500 m, the surface cannot be considered homogeneous. POLDER's capacity to observe an area from various view angles allows for measurement of the complete BRDF with the successive images acquired along different flight axes over the experimental site.

4. Equipment

4.1 Sensor/Instrument Description

4.1.1 Collection Environment

It is mandatory to operate POLDER in totally clear sky conditions, so that the distribution of irradiance does not change from one measurement to another, and so that calculation of reflectances in absolute units from radiances is possible.

4.1.2 Source/Platform

During IFC-1 and IFC-2, the POLDER instrument was installed alternatively on the NASA ARC C-130 aircraft or the NASA Wallops Flight Facility (WFF) helicopter. The POLDER instrument was deployed on the C-130 only in the SSA. The data described in this document were collected from the C-130 platform.

4.1.3 Source/Platform Mission Objectives

The POLDER mission objective was to collect multiangle and multispectral bidirectional reflectance data over flux tower and auxiliary sites to study the boreal forest canopy.

4.1.4 Key Variables

POLDER measures multispectral radiance in the visible and near infrared domain as a function of solar and view geometry.

4.1.5 Principles of Operation

The POLDER optical system consists of a telecentric lens, a filter wheel, and a CCD array as a detector. The light is almost vertically incident on the filter wheel after passing the telecentric lens. The CCD array (288 x 384 elements) can collect 2-D images. The filter wheel contains 10 slots for spectral filters and polarizers. The first channel is reserved for dark current measurement, while the others allow measurements in five spectral bands (443, 550, 670, 864, and 910 nm). Two spectral bands (443 and 864 nm) are associated with three polarized filters oriented by steps of 60°. A 10-channel image, corresponding to the 10 positions of the filter wheel, is collected within 3 seconds, and this acquisition is repeated every 10 seconds.

The POLDER optical system was installed in the forward bay of the C-130. Aircraft position and attitude parameters provided by the onboard navigation system were recorded by the POLDER electronics subsystem for data postprocessing. Typical flight altitude was 5500 m. Different flight lines were flown on each site to collect images in the principal, perpendicular, and 45° solar planes.

4.1.6 Sensor/Instrument Measurement Geometry

The long axis of the CCD array was set parallel to the aircraft longitudinal axis. An inclinometer was used to record the initial bias between the optical axis and true nadir.

4.1.7 Manufacturer of Sensor/Instrument

The instrument was designed and manufactured by Laboratoire d'Optique Atmosphèrique (LOA) 59655 Villeneuve d'Ascq Cedex Lille, France

4.2 Calibration

Radiometric calibration data were acquired at LOA by J.-Y. Balois before and after the BOREAS experiment (11-May-1994, 24-Oct-1994) using a calibrated integration sphere. The whole exit port of the integration sphere is used to derive the equalization coefficients g_{ij}^{ka} (see definition in Section 9.2.1). For absolute calibration, the exit port is reduced by a diaphragm to illuminate only a small circular area in the center of the CCD array. Readings of 15 x 15 pixel windows are corrected for dark current and averaged to obtain the absolute calibration coefficients A^{ka} (see Section 9.2.1)

Other calibration experiments were made during the BOREAS experiment using a 30-inch (0.76-m) diameter portable hemisphere that is owned and operated by NASA's Goddard Space Flight Center (GSFC). This portable hemisphere was made available to Remote Sensing Science (RSS)-20 by Brian Markham and John Schaffer. The calibration of POLDER was performed at the Prince Albert airport when POLDER was installed in C-130 aircraft on 27-May-1994 and 21-Jul-1994.

There is a good agreement between the LOA calibration and the first in situ calibration. The second in situ calibration shows discrepancies greater than 10% for all channels. The reasons for such discrepancies are still unknown.

4.2.1 Specifications

The general specifications of calibration accuracy were 5% absolute accuracy, 3% interband relative calibration accuracy, and 2% multitemporal relative calibration accuracy.

4.2.1.1 Tolerance

A general rise of the sensitivity was noted between the two calibration experiments made at LOA (11-May-1994, 24-Oct-1994): 8% in the blue (443 nm), 3.5% in the green (550 nm) and in the red (670 nm), 5.5% for the 864-nm channel, and 5% for the 910-nm channel. For subsequent processing, mean coefficients obtained at LOA are used.

4.2.2 Frequency of Calibration

The instrument is generally calibrated once before an experimental campaign and once after the campaign. Calibration was performed at LOA on 11-May-1994 and 24-Oct-1994. Onsite calibration was performed on 27-May-1994 and 21-Jul-1994.

4.2.3 Other Calibration Information

Having the spectral radiance at the outport of the sphere or the hemisphere and knowing the sensitivity of the various filters and the spectral value of the solar exoatmospheric irradiance, the normalized radiance is computed using:

$$L_{norm} = \pi \frac{\sum_{i=1}^{n} L(\lambda_{i}) S(\lambda_{i}) \delta \lambda_{i}}{\sum_{i=1}^{n} E(\lambda_{i}) S(\lambda_{i}) \delta \lambda_{i}}$$

where: L: spectral radiance ($W/m^2/sr/\mu m$) as a function of wavelength (λ_i)

S: spectral sensitivity as a function of wavelength

E: spectral exoatmospheric solar irradiance (W/m²/µm) as a function of wavelength

The normalized radiance is used (see Section 9.2.1) to derive the absolute calibration coefficient Aka.

5. Data Acquisition Methods

For the C-130 data, the onboard navigation system gives information on the viewing geometry of each pixel. Therefore, the location and attitude data yield an approximate position of a given surface target in all POLDER images. There is a time lag of 10 seconds between each image acquisition sequence. For a typical C-130 flight altitude and speed, an angular resolution of approximately 10 degrees is obtained.

6. Observations

- **6.1 Data Notes**None.
- 6.2 Field Notes

None.

7. Data Description

7.1 Spatial Characteristics

7.1.1 Spatial Coverage

The following are North American Datum of 1983 (NAD83) coordinates of locations that were visited:

	BORIS	West	North	UTM	UTM	UTM
Site	Grid ID	Longitude	Latitude	Easting	Northing	Zone
SSA Fen	F0L9T	104.61797	53.80206	525190.7	5961344.0	13
SSA Old Aspen (OA)	C3B7T	106.19779	53.62890	420821.8	5942678.0	13
SSA Old Black Spruce (OBS)	G8I4T	105.11779	53.98718	492306.1	5981879.0	13
SSA Old Jack Pine (OJP)	G2L3T	104.69203	53.91634	520257.0	5974035.0	13
SSA Young Jack Pine (YJP)	F8L6T	104.64527	53.87581	523350.7	5969540.0	13

7.1.2 Spatial Coverage Map

Not available.

7.1.3 Spatial Resolution

The pixel size for POLDER images from the C-130 at an altitude of 5500 m is 35 m.

7.1.4 Projection

Not applicable.

7.1.5 Grid Description

Not applicable.

7.2 Temporal Characteristics

7.2.1 Temporal Coverage

POLDER data were collected on one of two platforms during the three 1994 IFCs. Dates are indicated in Section 7.2.2. Most experiments took place in the morning, except the following: 21-Jul: OJP (around noon), YJP, Fen.

7.2.2 Temporal Coverage Map

Site	BORIS Grid	IFC-1	IFC-2	IFC-3
Fen	F0L9T	07/24		
OA	G3B7T	05/26,05/31		
OBS	G8I4T	05/31,06/01	07/21	
OJP	G2L3T	05/31,06/01	07/21, 07/24	
YJP	F8L6T	06/01	07/21	

7.2.3 Temporal Resolution

See Section 7.2.1.

7.3 Data Characteristics

7.3.1 Parameter/Variable

The parameters contained in the data files on the CD-ROM are:

Column Name

SITE_NAME
SUB_SITE
DATE_OBS
WAVELENGTH
SOLAR_ZEN_ANG
VIEW_ZEN_ANG
RELATIVE_VIEW_AZ_ANG
MEAN_REFL
MEAN_SURF_REFL
CRTFCN_CODE
REVISION_DATE

7.3.2 Variable Description/Definition

The descriptions of the parameters contained in the data files on the CD-ROM are:

Column Name	Description
SITE_NAME	The identifier assigned to the site by BOREAS, in the format SSS-TTT-CCCCC, where SSS identifies the portion of the study area: NSA, SSA, REG, TRN, and TTT identifies the cover type for the site, 999 if unknown, and CCCCC is the identifier for site, exactly what it means will vary with site type.
SUB_SITE	The identifier assigned to the sub-site by BOREAS, in the format GGGGG-IIIII, where GGGGG is the group associated with the sub-site instrument e.g. HYD06 or STAFF, and IIIII is the identifier for sub-site, often this will refer to an instrument.
DATE_OBS	The date on which the data were collected.
WAVELENGTH	Spectral wavelength at which the measurement was acquired.
SOLAR_ZEN_ANG	The angle from the surface normal (straight up) to the sun during the data collection.
VIEW_ZEN_ANG	The angle from the surface normal (straight up) to the observing instrument during the data collection.
RELATIVE_VIEW_AZ_ANG	The azimuthal angle at which the radiant energy was traveling when measured by the sensor, relative to the solar azimuth. The relative view azimuth angle increases in a clockwise direction from the solar position.
MEAN_REFL	The mean reflectance factor.
MEAN_SURF_REFL	The mean surface reflectance factor (atmospherically corrected).
CRTFCN_CODE	The BOREAS certification level of the data.

Examples are CPI (Checked by PI), CGR (Certified by Group), PRE (Preliminary), and CPI-??? (CPI

but questionable).

REVISION_DATE The most recent date when the information in the referenced data base table record was revised.

7.3.3 Unit of Measurement

The measurement units for the parameters contained in the data files on the CD-ROM are:

Column Name	Units
SITE NAME	[none]
SUB SITE	[none]
DATE_OBS	[DD-MON-YY]
WAVELENGTH	[micrometers]
SOLAR_ZEN_ANG	[degrees]
VIEW_ZEN_ANG	[degrees]
RELATIVE_VIEW_AZ_ANG	[degrees]
MEAN_REFL	[percent]
MEAN_SURF_REFL	[percent]
CRTFCN_CODE	[none]
REVISION_DATE	[DD-MON-YY]

7.3.4 Data Source

The sources of the parameter values contained in the data files on the CD-ROM are:

Column Name	Data Source
SITE_NAME	[Assigned by BORIS Staff]
SUB_SITE	[Assigned by BORIS Staff]
DATE_OBS	[RSS20 team]
WAVELENGTH	[POLDER instrument]
SOLAR_ZEN_ANG	[Calculated using position and time]
VIEW_ZEN_ANG	[Calculated using geometry]
RELATIVE_VIEW_AZ_ANG	[Calculated using geometry]
MEAN_REFL	[POLDER instrument]
MEAN_SURF_REFL	[POLDER instrument and atmospheric correction]
CRTFCN_CODE	[Assigned by BORIS Staff]
REVISION_DATE	[Assigned by BORIS Staff]

7.3.5 Data Range

The following table gives information about the parameter values found in the data files on the CD-ROM.

Column Name	Minimum Data Value	Maximum Data Value	Missng Data Value	Unrel Data Value	Below Detect Limit	Data Not Cllctd
SITE NAME	SSA-90A-FLXTR	SSA-YJP-FLXTR	None	None	None	None
SIIE_NAME	SSA-9UA-FLAIR	SSH-IOF-FLVIK	None	None	None	None
SUB_SITE	RSS20-BRF01	RSS20-BRF01	None	None	None	None
DATE_OBS	26-MAY-94	24-JUL-94	None	None	None	None
WAVELENGTH	0.443	0.910	None	None	None	None
SOLAR_ZEN_ANG	33.4	56.6	None	None	None	None
VIEW_ZEN_ANG	.3	55.5	None	None	None	None
RELATIVE VIEW AZ ANG	0	360	None	None	None	None

MEAN_REFL	2	77	-999	None	None	None
MEAN_SURF_REFL	.1	96.7	None	None	None	None
CRTFCN_CODE	CPI	CPI	None	None	None	None
REVISION_DATE	15-JAN-99	15-JAN-99	None	None	None	None
Minimum Data Value Maximum Data Value Missng Data Value	The maximum v	alue found in	the colum	n. a. This		l to
Unrel Data Value	The value that to indicate at parameter val	ue, but the at t indicates un attempt was ue, but the vathe analysis	reliable made to d lue was d	data. letermin leemed t	This is e the	used
Below Detect Limit	The value that instruments do indicate that parameter value that the parameter and that the parameter tha		rameter v s. This s made to alysis pe s below t	ralues b is used determ rsonnel	l to nine the . determi	
Data Not Cllctd This value indicates that no attempt was made to determine the parameter value. This usually indicates that BORIS combined several similar but not identical data sets into the same data base table but this particular science team did not measure that parameter.						ole
Blank Indicates	that blank space	s are used to	denote th	at type	of valu	ıe.
N/A Indicates	that the value is	s not applicab	le to the	respec	tive col	umn.
None Indicates	that no values of	f that sort we	re found	in the	column.	

7.4 Sample Data Record

The following is a sample of the first few records from the data table on the CD-ROM:

```
SITE_NAME, SUB_SITE, DATE_OBS, WAVELENGTH, SOLAR_ZEN_ANG, VIEW_ZEN_ANG, RELATIVE_VIEW_AZ_ANG, MEAN_REFL, MEAN_SURF_REFL, CRTFCN_CODE, REVISION_DATE
'SSA-OBS-FLXTR', 'RSS20-BRF01',21-JUL-94,.443,33.6,51.9,350.5,12.0,5.0,'CPI',
15-JAN-99
'SSA-OBS-FLXTR', 'RSS20-BRF01',21-JUL-94,.443,33.6,47.1,349.6,12.0,5.0,'CPI',
15-JAN-99
'SSA-OBS-FLXTR', 'RSS20-BRF01',21-JUL-94,.443,33.6,40.8,348.6,11.0,5.2,'CPI',
15-JAN-99
'SSA-OBS-FLXTR', 'RSS20-BRF01',21-JUL-94,.443,33.6,33.7,346.9,11.0,5.5,'CPI',
15-JAN-99
'SSA-OBS-FLXTR', 'RSS20-BRF01',21-JUL-94,.443,33.6,25.0,342.5,10.0,4.7,'CPI',
15-JAN-99
'SSA-OBS-FLXTR', 'RSS20-BRF01',21-JUL-94,.443,33.6,15.1,333.3,8.0,3.9,'CPI',
15-JAN-99
```

8. Data Organization

8.1 Data Granularity

The smallest amount of data that can be ordered from this data set is a day's worth of data for a given site.

8.2 Data Format(s)

The Compact Disk-Read-Only Memory (CD-ROM) files contain American Standard Code for Information Interchange (ASCII) numerical and character fields of varying length separated by commas. The character fields are enclosed with single apostrophe marks. There are no spaces between the fields.

Each data file on the CD-ROM has four header lines of Hyper-Text Markup Language (HTML) code at the top. When viewed with a Web browser, this code displays header information (data set title, location, date, acknowledgments, etc.) and a series of HTML links to associated data files and related data sets. Line 5 of each data file is a list of the column names, and line 6 and following lines contain the actual data.

9. Data Manipulations

9.1 Formulae

See Section 9.2.

9.1.1 Derivation Techniques and Algorithms

See Section 9.2.

9.2 Data Processing Sequence

9.2.1 Processing Steps

9.2.1.1 Level 1 Images

The raw radiometric data are digital numbers noted $CN_{ij}{}^{ka}$, where i, j are indices of pixel location on the CCD matrix, k is the wavelength, and a is the polarizer number for spectral bands comprising three polarizers. For the other spectral bands, a is meaningless. The processing from level 0 to level 1 data consists of the transformation of raw data into data proportional to normalized radiances $S_{ij}{}^{ka}$, according to the equation:

$$S_{ij}^{ka} = \frac{\sqrt{6} \left(C N_{ij}^{ka} - \overline{C N_{j}^{0}} \right)}{t A^{ka} g_{ij}^{ka} e^{-\beta^{k} (T - T_{0})}}$$

where: t₀ -- reference exposure time, used in calibration : 100 ms

t -- exposure time during operation

CN_i⁰ -- average of line j of dark current

Aka -- calibration coefficient

 g_{ij}^{ka} -- relative sensitivity (high and low frequency) of instrumental (optics + CCD) transmission. It is normalized such that the local average of g_{ij}^{ka} at the matrix center equals 1.

β^k -- sensitivity of absolute calibration to CCD temperature

T₀ -- CCD temperature during calibration

T -- CCD temperature in operation

 $S_{ij}^{\ ka}$ -- is a digital number proportional to the observed normalized radiance (for the channels without polarizers)

$$S_{ij}^{ka} = 10000 \frac{\pi \mathcal{L}_{ij}^k}{\mathcal{E}^k}$$

where: $L>_{ij}k$ -- observed radiance (W/m²/sr/µm) for pixel i, j in band k E^k -- exoatmospheric solar irradiance in band k (W/m²/µm)

For polarized bands, the aircraft displacement between successive channel acquisition must be taken into account to obtain a normalized spectral radiance from the three polarized channels

$$\frac{1}{3} \sum_{x=1}^{3} S_{xy}^{kx} = 10000 \frac{\pi Z_{xy}^{k}}{E^{k}}$$

where (x,y) are surface coordinates that refer to CCD pixels coordinates (i,j) in each of the polarized channels viewing the same ground point (x,y). The level 1 images provide data that for each band are equal to the right-hand side of the two previous equations. They are essentially normalized radiances.

9.2.1.2 BRDF Over Tower Sites

Radiance to Reflectance:

The radiance is converted to reflectance $R_{ij}{}^k$ according to

$$R_{ij}^{k} = \frac{\pi L_{ij}^{k}}{E^{k} \cos \theta_{s}}$$

where \emptyset_s is the solar zenith angle.

Image Coregistration (for C-130 data):

The POLDER electronics subsystem recorded the aircraft position and attitude parameters during the flights. The initial bias between the inertial reference system and the POLDER optical axis was measured before each flight. Attitude and location data should be sufficient to correct POLDER images for geometry. However, the uncertainty in the aircraft position was too large. A ground control point technique was therefore used to fine-tune the geometric multi-image registration of the whole set.

To derive the BRDF over tower sites, a simple translation was made on geocoded images. The reflectance measurements were then averaged on a 5 x 5 pixel window (175 x 175 m²) around each tower site to minimize residual misregistration effects.

Atmospheric corrections:

The atmospheric correction algorithm, the Second Simulation of the Satellite Signal in the Solar Spectrum (6S) (Vermote et al., 1997) was applied to the measured reflectances to produce corrected reflectances. This was performed only on the C-130 data, not to helicopter data. A mid-Arctic summer atmospheric model and a continental aerosol model were selected to characterize the atmosphere above

the BOREAS sites. Moreover, the total aerosol optical depth for the full atmosphere and the below-aircraft aerosol optical depth, both at 550 nm, are necessary inputs of the algorithm. These optical thickness measurements were obtained from the BORIS Information System (BORIS) data base: total optical depth was retrieved from RSS-11 (Markham/Schafer) sunphotometer data at Prince Albert airport and YJP sites; above-aircraft thicknesses come from RSS-12 (Wrigley/Spanner); interpolations were made to derive values at 550 nm. Aerosol optical depths are given in the following table for each date and site. All flight days of IFC-1 and IFC-2 were very clear, with an average value of the total optical aerosol depth of 0.10 at 550 nm.

The following table summarizes the C-130 and solar and atmospheric conditions during POLDER data acquisitions:

Site	Date	Sun Zenith angle (deg)	Aerosol thickness at 550 nm (total/below aircraft)
Fen	24-Jul	44.4 - 49.3	0.080/0.020
	03-May	38.4 - 42.8	0.130/0.055
OJP	01-Jun	48.4 - 51.4	0.095/0.050
	21-Jul	33.8 - 35.0	0.120/0.095
	24-Jul	40.5 - 43.3	0.095/0.020
	26-May	39.4 - 41.8	0.115/0.075
OA	31-May	6.5 - 52.5	0.070/0.025
	01-Jun	44.0 - 47.0	0.095/0.050
YJP	21-Jul	35.5 - 37.2	0.115/0.090
	31-May	35.5 - 37.4	0.135/0.070
OBS	01-Jun	53.5 - 56.4	0.060/0.030
	21-Jul	33.4 - 33.7	0.115/0.090

9.2.2 Processing Changes

None.

9.3 Calculations

9.3.1 Special Corrections/Adjustments None.

9.3.2 Calculated Variables

Radiance and reflectance were calculated.

9.4 Graphs and Plots

None.

10. Errors

10.1 Sources of Error

For images and BRDF data, there is some uncertainty in the absolute calibration coefficient, as illustrated by the calibration tables shown above. For the BRDF data, an additional source of error results from image registration. In the processing, it is assumed that the position of the site is the same for all images of the sequence, which can induce a error in the location of less than 1 pixel. These errors are lessened with the spatial averaging procedure. The smoothing aspect of the BRDF data tends to show that the misregistration errors are not critical.

10.2 Quality Assessment

10.2.1 Data Validation by Source

The POLDER data have been tested against the four-scale BRDF reflectance model (Leblanc et al., 1997) as well as against the PARABOLA data and the DART 3-D BRDF model (Gastellu-Etchegorry et al., 1997).

10.2.2 Confidence Level/Accuracy Judgment

The uncertainty associated with POLDER spectral reflectances values, taking into account only error in the absolute calibration coefficient, is approximately less than 0.005 for the visible channels and 0.01 for the near-infrared channel. The confidence level in these measurements is good because of their reproducibility for different axes during the same flight.

10.2.3 Measurement Error for Parameters

Not available.

10.2.4 Additional Quality Assessments

The directional reflectances obtained with POLDER data corrected from atmospheric effects for the flux tower or auxiliary sites can be compared to similar data made by other instruments.

10.2.5 Data Verification by Data Center

BORIS staff has looked at some of the POLDER imagery from the C-130. It appears that there are some registration problems between bands in some of the imagery.

11. Notes

11.1 Limitations of the Data

None.

11.2 Known Problems with the Data

None.

11.3 Usage Guidance

Not applicable.

11.4 Other Relevant Information

None.

12. Application of the Data Set

This data set can be used for BRDF model inversion and BRDF direct model cross-checking.

13. Future Modifications and Plans

None.

14. Software

14.1 Software Description

None given.

14.2 Software Access

Raw data and processing software may be available upon request. See Section 2.3.

15. Data Access

The POLDER C-130 measurements of surface BRDF are available from the Earth Observing System Data and Information System (EOSDIS) Oak Ridge National Laboratory (ORNL) Distributed Active Archive Center (DAAC).

15.1 Contact Information

For BOREAS data and documentation please contact:

ORNL DAAC User Services Oak Ridge National Laboratory P.O. Box 2008 MS-6407 Oak Ridge, TN 37831-6407 Phone: (423) 241-3952

Fax: (423) 574-4665

E-mail: ornldaac@ornl.gov or ornl@eos.nasa.gov

15.2 Data Center Identification

Earth Observing System Data and Information System (EOSDIS) Oak Ridge National Laboratory (ORNL) Distributed Active Archive Center (DAAC) for Biogeochemical Dynamics http://www-eosdis.ornl.gov/.

15.3 Procedures for Obtaining Data

Users may obtain data directly through the ORNL DAAC online search and order system [http://www-eosdis.ornl.gov/] and the anonymous FTP site [ftp://www-eosdis.ornl.gov/data/] or by contacting User Services by electronic mail, telephone, fax, letter, or personal visit using the contact information in Section 15.1.

15.4 Data Center Status/Plans

The ORNL DAAC is the primary source for BOREAS field measurement, image, GIS, and hardcopy data products. The BOREAS CD-ROM and data referenced or listed in inventories on the CD-ROM are available from the ORNL DAAC.

16. Output Products and Availability

16.1 Tape Products

None.

16.2 Film Products

None.

16.3 Other Products

These data are available on the BOREAS CD-ROM series.

17. References

17.1 Platform/Sensor/Instrument/Data Processing Documentation None.

17.2 Journal Articles and Study Reports

Bicheron, P., M. Leroy, O. Hautecoeur, and F.M. Brèon. 1997. Enhanced discrimination of boreal forest covers from the airborne polarization and directionality of Earth reflectances (POLDER) instrument. Journal of Geophysical Research 102(D24): 29,517-29,528.

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Newcomer, J., D. Landis, S. Conrad, S. Curd, K. Huemmrich, D. Knapp, A. Morrell, J. Nickeson, A. Papagno, D. Rinker, R. Strub, T. Twine, F. Hall, and P. Sellers, eds. 2000. Collected Data of The Boreal Ecosystem-Atmosphere Study. NASA. CD-ROM.

Sellers, P. and F. Hall. 1994. Boreal Ecosystem-Atmosphere Study: Experiment Plan. Version 1994-3.0, NASA BOREAS Report (EXPLAN 94).

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Sellers, P., F. Hall, and K.F. Huemmrich. 1996. Boreal Ecosystem-Atmosphere Study: 1994 Operations. NASA BOREAS Report (OPS DOC 94).

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Sellers, P., F. Hall, H. Margolis, B. Kelly, D. Baldocchi, G. den Hartog, J. Cihlar, M.G. Ryan, B. Goodison, P. Crill, K.J. Ranson, D. Lettenmaier, and D.E. Wickland. 1995. The boreal ecosystem-atmosphere study (BOREAS): an overview and early results from the 1994 field year. Bulletin of the American Meteorological Society. 76(9):1549-1577.

Sellers, P.J., F.G. Hall, R.D. Kelly, A. Black, D. Baldocchi, J. Berry, M. Ryan, K.J. Ranson, P.M. Crill, D.P. Lettenmaier, H. Margolis, J. Cihlar, J. Newcomer, D. Fitzjarrald, P.G. Jarvis, S.T. Gower, D. Halliwell, D. Williams, B. Goodison, D.E. Wickland, and F.E. Guertin. 1997. BOREAS in 1997: Experiment Overview, Scientific Results and Future Directions. Journal of Geophysical Research 102(D24): 28,731-28,770.

Vermote E.F., D. Tanre, J.L. Deuze, M. Herman, and J.J. Morcrette. 1997. Second Simulation of the Satellite Signal in the Solar Spectrum, 6S: An overview. IEEE Transactions On Geoscience And Remote Sensing 35: (3) 675-686.

17.3 Archive/DBMS Usage Documentation

None.

18. Glossary of Terms

None.

19. List of Acronyms

6S - Second Simulation of the Satellite signal in the Solar Spectrum

ARC - Ames Research Center

ASCII - American Standard Code for Information Interchange

BOREAS - BOReal Ecosystem-Atmosphere Study

BORIS - BOREAS Information System

BPDF - Bidirectional Polarization Distribution FunctionBRDF - Bidirectional Reflectance Distribution Function

CCD - Change Coupled Device

CD-ROM - Compact Disk-Read-Only Memory
DAAC - Distributed Active Archive Center

EOS - Earth Observing System

EOSDIS - EOS Data and Information System

FOV - Field of View

GIS - Geographic Information System
GSFC - Goddard Space Flight Center
HTML - HyperText Markup Language
IFC - Intensive Field Campaign

LAI - Leaf Area Index

LOA - Laboratoire d'Optique Atmospherique

NAD83 - North American Datum of 1983

NASA - National Aeronautics and Space Administration

NSA - Northern Study Area

OA - Old Aspen

OBS - Old Black Spruce OJP - Old Jack Pine

ORNL - Oak Ridge National Laboratory
PANP - Prince Albert National Park

POLDER - POLarization and Directionality of Earth's Reflectances

RSS - Remote Sensing Science
SSA - Southern Study Area
URL - Uniform Resource Locator
UTM - Universal Transverse Mercator
WFF - Wallops Flight Facility

YJP - Young Jack Pine

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Leroy, M., F.-M. Brèon, P. Bicheron, and O. Hautecoeur, "Estimation of Photosynthetic Capacity using POLDER Polarization." In Collected Data of The Boreal Ecosystem-Atmosphere Study. Eds. J. Newcomer, D. Landis, S. Conrad, S. Curd, K. Huemmrich, D. Knapp, A. Morrell, J. Nickeson, A. Papagno, D. Rinker, R. Strub, T. Twine, F. Hall, and P. Sellers. CD-ROM. NASA, 2000.

Also, cite the BOREAS CD-ROM set as:

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This BOREAS RSS-20 data set contains measurements of surface BRDF made by the POLDER instrument over several surface types (pine, spruce, fen) of the BOREAS SSA during the 1994 IFCs. Single-point BRDF values were acquired either from the NASA ARC C-130 aircraft or from a NASA WFF helicopter. A related data set collected from the helicopter platform is available as is POLDER imagery acquired from the C-130. The data are stored in tabular ASCII files.

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